

Study on the Influence of Grid-Connected Photovoltaic Generation on Power Grid Operation

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Keywords: Photovoltaic generation, Grid connection, Grid operation, Relay protection, Voltage

Abstract: Photovoltaic generation has been widely studied and applied for its low cost, environmental protection, energy saving and many other advantages. However, the grid connection of photovoltaic generation will inevitably affect the operation of the power grid. Based on the safe and stable operation of the power grid, corresponding precautions should be taken for the impact of grid-connected photovoltaic generation on grid operation.

1. Introduction

With the rapid development of the social economy, the shortage of resources and the pollution of the environment have become major problems faced by all countries in the world, directly related to the survival and sustainable development of human beings. In order to alleviate the pressure caused by resource shortage and environmental pollution, all countries have developed a green energy development plan that suits their national conditions, and a consensus has been reached on the development and utilization of renewable energy. Photovoltaic generation has been widely concerned and applied for its wide energy acquisition, low cost, high reliability and non-pollution. In recent years, grid-connected photovoltaic generation technology has developed rapidly in China, but due to its short development process, there must be many immaturity in technology, which will have certain adverse effects on the operation of the power grid. It is necessary to take corresponding measures. To avoid the impact of grid-connected photovoltaic generation on grid operation stability and quality, and give full play to the advantages of photovoltaic generation.

2. The Impact of Grid-Connected Photovoltaic Generation on Grid Operation

2.1 Impact on Grid Planning

The construction period of the photovoltaic power station is short, and it can be connected to the grid for power generation in a short time. With the explosive growth of the installed capacity of photovoltaic power generation, the existing power grid cannot absorb the new power generation. The large-capacity development of grid-connected photovoltaic generation, its load and reverse power will also show a certain change, which makes the original power grid difficult to meet the demand ^[1].

2.2 Influence on Peak Load Regulation of Power Grid

At present, photovoltaic generation is immature, the automation function is imperfect, and it is difficult to make corresponding adjustments with changes in grid voltage and frequency. The change of photovoltaic generation will directly lead to the reduction of the grid's schedulable power generation capacity, which will make the grid control and dispatching work more and more difficult ^[2].

Statistics show that the time period with the strongest illumination often does not overlap with the maximum load period of the early peak. The maximum time for photovoltaic generation lags behind the morning peak load for about 30 minutes, which means that after the early peak of the power grid, when the power load drops rapidly, the photovoltaic generation is growing, showing reverse peak characteristics. When photovoltaic generation is connected to the grid and the scale is

increased, it will have to temporarily regulate the unit shutdown peak load, which may affect the standby of the evening peak.

2.3 Impact on Electrical Primary Systems

When photovoltaic generation is connected to the grid, it is necessary to design the voltage level and wiring form of the PV system into the network according to factors such as the capacity of the generator set, the distribution of the surrounding distribution network, and economic and technical indicators, as shown in Table 1.

Table 1 Pv System Access Voltage Level and Wiring Form

Power capacity	Grid connected voltage	Wiring form
< 1MWp	10kV	T connection access to low voltage distribution network
< 30MWp	10kV~35kV	T connection access to 10kV or 35kV bus
≥30MWp	110kV	Access to high voltage transmission bus

The access form of the photovoltaic system has different effects on the power supply system: the T connection affects the normal distribution network topology; and the bus access mode of the large-capacity photovoltaic system changes the power distribution of the original power supply system.

2.4 Impact on Power Quality

The function of the power distribution system has changed from the access of photovoltaic generation, from the original simple distribution of electrical energy to the collection, transmission and distribution of electrical energy. Unlike conventional generator sets, photovoltaic generation systems contain a large number of converter devices, resulting in increased harmonic content in the power system.

When photovoltaic generation is connected to the grid, the on-line power quality monitoring device of the photovoltaic system should be assembled at the grid connection point or the metering point of the gateway to monitor the power generation quality of the grid-connected photovoltaic generation in real time to avoid harmonic pollution. For large and medium-sized PV systems, the monitoring device should have the function of real-time transmission of remote data; for small systems, the monitoring device should have at least one year of monitoring data and remote access capability.

2.4.1 Harmonic Pollution

Since the electric energy generated by the photovoltaic power is direct current, it needs to be converted by a large-capacity inverter when it is connected to the grid. In this process, the application of power electronic devices will lead to the generation of a large number of harmonics, in which higher harmonics still have amplification phenomenon during power transmission. When the harmonic content exceeds the standard, measures must be taken to suppress it. For example, the filter is used to filter a certain harmonic and then connected to the grid or double closed-loop control to realize harmonic control.

2.4.2 Voltage Fluctuations and Flicker

When photovoltaic power generation is connected to the grid, consideration should be given to the effects of various factors on the fluctuation and flicker of the grid-connected power grid.

(1) Since the power generation efficiency of photovoltaic systems is greatly affected by light, the power generation capacity of photovoltaic systems fluctuates greatly. Therefore, it is necessary to track the maximum power generated by the photovoltaic system. When the light conditions change, the system automatically adjusts the output voltage so that the generated power always reaches its maximum state.

(2) When the photovoltaic system is in operation, it is affected by the parameter setting of its control system, and its power generation will periodically change, affecting the end voltage.

(3) The start and stop frequent of the PV system leads to large voltage fluctuations.

(4) Due to the low voltage level of the grid-connected PV system, when the output power is fluctuated, it directly affects the end voltage.

In order to ensure the quality of the output power of the photovoltaic system, it is necessary to specify the voltage fluctuation range. With reference to the voltage of the power system is connected to the grid, the voltage fluctuation of the power system is small, and the long-term (168h) grid-connected flicker limitation of photovoltaic power generation should be established, and the limits are also required to meet the relevant standards.

2.5 Impact on Grid Protection Operation

2.5.1 Impact on Reclosing

In China, for single-supply radiating type distribution lines, three-phase reclosing switch is generally used to try to restore power after tripping after fault. If the photovoltaic system is connected to the distribution network, when the fault occurs in the upstream of the photovoltaic, if the upstream switch of the photovoltaic is turned off but the photovoltaic grid-connected switch is still in place, the photovoltaic carries an downstream island with its downstream load, as shown in Figure 1, the fault occurred at point d1, which tripped circuit breakers 1 and 2.

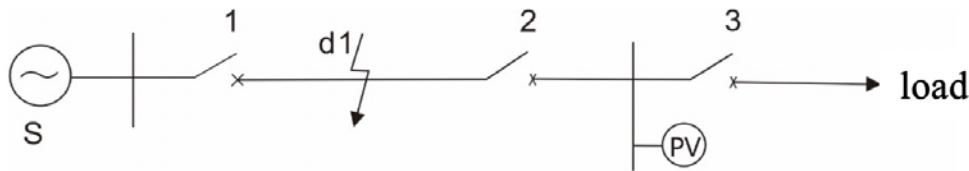


Fig.1 Photovoltaic Generation System Becomes Islanding Condition

At this time, if the islanding condition of the photovoltaic station can be continued, the reclosing of the line may have two adverse effects:

(1) If the output power of the photovoltaic station operating on an islanding condition is insufficient to support the load, but the island state cannot be detected immediately, the frequency drop due to the active deficiency may occur during this time before the reclosing action. The voltage between the grid voltage and the islanding is not synchronized. At this time, if it coincides, there is a possibility of non-synchronous closing, which will cause a big impact on the photovoltaic and downstream loads. This shock may generate a large current, causing the relay protection to malfunction.

(2) If the fault occurs downstream of the photovoltaic, but the short-circuit current output by the photovoltaic station is small, the relay protection does not work, although the circuit breaker of the main power grid is tripped, but the photovoltaic is still connected to the grid, continuously injecting into the fault point. At this time a certain amount of short-circuit current is possible to extend the arc extinguishing time of the fault point beyond the time of the reclosing action, so that the coincidence is similar to a permanent fault, causing the coincidence to fail. Due to the problems caused by the reclosing of photovoltaics after grid connection, appropriate measures must be taken to avoid them. For example, for the problem of extinction time, the reclosing time can be extended. If the problem of non-synchronous closing is to be avoided, the synchronous closing can be performed, but the line voltage change is added.

2.5.2 Impact on Overcurrent Protection

For low-voltage distribution networks, three-stage overcurrent protection is very common, but grid-connected photovoltaic power generation can also cause problems with overcurrent protection, such as misoperation.

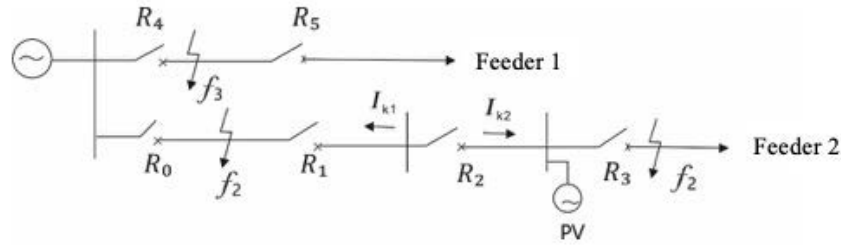


Fig.2 Analysis of the Misconnection of Feeder Protection Caused by Photovoltaic Generation

The problem of overcurrent protection is that the photovoltaic grid-connected generation system injects additional short-circuit current to the fault point, and this short-circuit current flows through the circuit breaker in the non-faulty area, causing the protection device to lose selectivity, as shown in Figure 2. When f_1 fails, the protection of the action should be R_0 and R_1 , so that the fault is correctly isolated, but since the photovoltaic station is downstream of R_2 , if the output short-circuit current of the photovoltaic station exceeds the fixed value of R_2 , it causes the misoperation of R_2 . Similarly, when the f_3 point fails, the protection R_1 also flows through the short-circuit current provided by a photovoltaic power station. At this time, if the short-circuit output is large, the short-circuit current flowing through R_1 is too large, which may cause the R_1 to misoperation. This is because in the overcurrent protection configured in 10kV, the direction judgment function is generally not provided, otherwise the line voltage change must be added.

2.5.3 Impact on Distance Protection

In the past, the situation that affected the distance protection mechanism of photovoltaic systems was: system short-circuit current from S (system power supply) and PV (photovoltaic generation system). Both are fault points and are not part of the incoming line of the system power supply. Its position is shown as d2 in Figure 3:

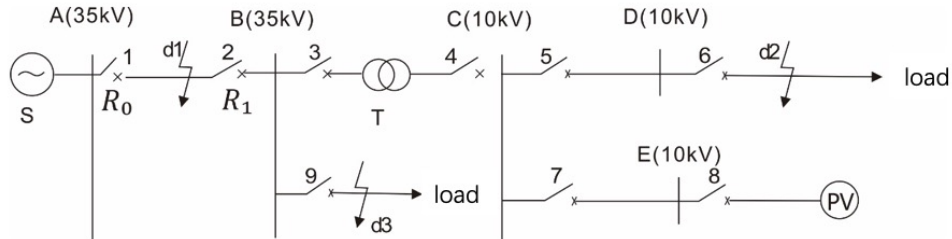


Fig.3 Analysis of the Impact of Photovoltaic Generation on Distance Protection

The photovoltaic system distance protection mechanism takes into account both voltage and current quantity protection. The increase of the assisted current in the photovoltaic system makes the current and the terminal voltage of the impedance relay increase at the same time, and does not affect the distance protection of the I segment of the original system.

The phase II current protection setting value is determined by the original system I section distance protection setting. Refer to the determination method of the current protection setting value of the II section, and set the distance protection setting value of the II section, and the action time limit must be higher than Δt . When the d2 point fails, the photovoltaic system will flow current to the fault point, so that the impedance value of the protection 1 is increased, and the protection range of the II section is shortened. This approach reduces the sensitivity of the protection mechanism, but does not affect its selectivity. Judging whether the distance protection reduces the sensitivity, it is necessary to analyze the short-circuit current of the fault point of the photovoltaic system and the normal running time to be determined. The condition for judging the distance sensitivity of the original system II is: under normal operating conditions, the short-circuit current value of the photovoltaic system supply is less than 0.1 times of the instantaneous value of the original system; conversely, the supply current value of the photovoltaic system is lower than the instantaneous value of the original system. When the value is 0.1 times larger, the sensitivity of the original system distance protection segment II may be lowered. Therefore, it is necessary to recalculate and

verify the set value to ensure the sensitivity of the original system II segment.

Refer to section III current protection setting method to calculate the distance protection setting value of section III. The determination of the starting impedance needs to avoid the minimum impedance load under normal operating conditions, and its operating time limit should be increased. Since the III section distance protection requires a high operation time limit and the photovoltaic system has a small capacity, the short-circuit current supplied to the III-section distance protection is also small, and it is not affected by the access of the photovoltaic system, so the influence of the injection-increasing current can be avoided.

As shown in Figure 3, if the d1 and d3 points fail, neither the distance protection 1 nor the protection 9 will be affected by the access of the photovoltaic system.

3. Conclusion

Based on the above-mentioned effects of grid-connected photovoltaic generation on grid operation, the following measures can be taken:

(1) In the planning of the power grid, the overall number of photovoltaic generation grids should be planned, considering the characteristics of the power generation load characteristics and the power load characteristics.

(2) In the planning of the power grid and the arrangement of the grid operation mode, the influence of the photovoltaic generation superimposed wind power on the peak load regulation of the power grid should be considered, and the peak load regulation capacity should be considered.

(3) In the design process, consider the compensation and suppression technical measures for the influence of photovoltaic generation on voltage and harmonics.

(4) Actively guide the simultaneous construction of photovoltaic generation and energy storage, and store the electrical energy in the battery energy storage system during the middle load, and output it at the peak of the evening.

(5) Advance research on the design and application of the relay protection equipment of the distribution network after the distribution network becomes a multi-power system, and pay attention to the compatibility of the scope and sensitivity of the distribution network protection.

References

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